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Effect of air pollution on the stock yield of heavy pollution enterprises in China's key control cities

Xianhua Wu [a, b, *], Shanshan Chen [b], Ji Guo [a, b], Ge Gao [a, c]

[a] Collaborative Innovation Center on Climate and Meteorological Disasters, Nanjing University of Information Science & Technology, Nanjing, 210044, China
[b] School of Economics and Management, Nanjing University of Information Science & Technology, Nanjing, 210044, China
[c] National Climate Center, Beijing, 10081, China

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ABSTRACT

Under the background of climate change, the haze days in China have increased significantly, which seriously hinders the sustainable development of society and arouses wide attention from the public. However, the researches on the effect of air pollution on the stock yield of heavy pollution enterprise in key control cities are quite limited, This paper collects the Air Quality Index (AQI) from key control cities above prefecture level in China as well as the stock yield data of these cities' heavy pollution enterprises in December from 2014 to 2016 and through multi-discontinuities regression model, testes the effect of air pollution on the stock yield of heavy pollution enterprise. The results show that: (1) Heavy air pollution (AQI = 300) has negative influence on the stock yield. (2) There exists time effect of air pollution on stock yield. Since the year 2014, heavy air pollution has exerted significantly negative influence on the stock yield in that 2013 may be the "first year" when the Chinese society began to take air pollution seriously. This paper gives a brief discussion on the cause of it and suggests that severe air pollution should be strictly controlled. Only by facing air pollution seriously, can we eliminate air pollution with collective wisdom and concerted efforts and achieve the sustainable development of city. Being the first study to look into the effect of air pollution on stock yield in key control cities in China, this paper provides empirical reference for government supervision departments, stock investors as well as enterprises.

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1. Introduction

Due to climate change, the environmental problem in China is increasingly serious (Mi et al., 2017). It is estimated that, from 2001 to 2010, the annual premature death toll caused by air pollution increases from 418 thousand to 514 thousand in China. According to the *Global Burden of Disease Study* conducted by the World Health Organization, the estimated premature death toll of China is higher and reaches 1.2 million in 2010.[1] Apart from health and lifespan, air pollution exerts adverse influences on other aspects of people's daily life as well, such as outdoor travel frequency, social interaction intention, and emotion. Through an analysis based on nationwide investigated data, Sexton (2012) found that when air quality warnings were given, the time people spent on outdoor activities would drop by 18%. Zheng et al. (2016) found that under severe air pollution, people were forced to dine out less often and they would get less satisfaction from dinning out. Graff and Neidell (2012) found that air pollution had a significant negative impact on productivity. Workers would feel distracted and down in the dumps during work. Besides, they would ask for leave frequently.

Air quality, which has attracted more and more attention from the public, will influence the psychology and behavior of people fully and thoroughly (Lundberg, 1996; Lepori, 2009). Similarly, environmental stress like weather change can influence stock market through investor sentiment. Saunders (1993) found there was a significant negative correlation between cloud coverage rate and stock yield. Hirshleifer and Shurnway (2003) verified the negative correlation between cloud coverage rate and stock yield. Lepori (2009) found that air pollution was negatively related to stock yield. Lu (2011) found weather index had no significant effects on stock yield while it could significantly influence the

* Corresponding author. Collaborative Innovation Center on Climate and Meteorological Disasters, Nanjing University of Information Science & Technology, Nanjing, 210044, China.
E-mail addresses: wxhua_77@nuist.edu.cn (X. Wu), 3467563554@qq.com (S. Chen), guoboshi@126.com (J. Guo), gaoge@cma.gov.cn (G. Gao).

[1] http://www.healtheffects.org/Internationl/GBD-Press-Release.pdf.

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turnover rate and volatility. Guo and Zhang (2016), through a multivariate progressive empirical approach based on the data of air quality and stock market of Shanghai, found that the stock market tended to have higher yield, lower turnover rate and volatility with excellent air quality.

As air quality and economic behavior are closely related, this paper, based on and improved the researches of Saunders (1993) and Hirshleifer and Shurnway (2003), attempts to study the impacts of air pollution on investor sentiment and stock yield under climate change from the aspect of city. Based on the air quality data of key control cities in China and the stock yields of heavy pollution enterprises, this paper, through regression discontinuity, discusses how seriously and in which year will air pollution influence stock market. The main features of the present study are as follows: First, the object of study is the data of the listed companies in 120 key control cities in China. It can reduce the errors of results caused by the differences between samples and thus get more persuasive conclusions. Second, as people feel different about air pollution degree, the impacts of air pollution at different levels on the stock yield are examined through regression discontinuity. This paper studies the effects of air pollution on the stock yield of heavy pollution enterprises in key control cities from different aspects, and then provides corresponding policy making suggestions on how to adapt to climate change and achieve sustainable development. The present study is a useful supplement to relevant researches. The rest of this paper is arranged as follows: Section 2 is literature review; Section 3 is introduction to indices and data; Section 4 is empirical analysis, and the last section is conclusions.

2. Literature review

As stock yield is influenced by air pollution through investor sentiment, the literature review of this paper is divided into two parts, namely, the researches on the effect of air pollution on investor sentiment and the researches on the effect of investor sentiment on stock yield. A brief introduction to the ways air pollution affects stock yield and the reason for using regression discontinuity in this paper is given.

In terms of the researches on the effect of air pollution on investor sentiment, in 1903, Nelson pointed out that it would be rather difficult for investors to deal in shares in muggy and rainy weathers as confidently and freely as in dry and sunny weathers. People tended to be happy and optimistic in good weather. Air quality, as one of the index for weather conditions, would affect the emotions and feelings of people at some extent, and would further affect the transactions in stock market. Evans et al. (1987) believed air pollution would influence people's sentiment and sentiment would affect decision making. People would feel angrier, more depressed, and more helpless when exposed to severe air pollution. Zhou (1999) believed weather conditions, which human beings rely on for existence and development, highly restricted the activities of people. Weather conditions had attracted extensive attention from people because any change in weather would significantly influence people's life. Eagles (1994) found that the lack of sunshine would make people depressed or even lead to a rise in suicide rate. In stock market, the mental activities of investors would be influenced by the surrounding environment, for instance, weather conditions, and the mental activities would further influence the exchange of stock. Mehra and Sah (2002) found that a minor mood swing could lead to a significant fluctuation in capital price. Lucey and Dowling (2005) found that weather and biologic changes could affect the exchange of stock through influencing people's sentiment. According to these researches, serious air pollution could cause negative emotions on investors and their will of transaction would become weaker, through which the stock yield would be affected.

In terms of the researches on the influence of investor sentiment on stock yield, Forgas and Bower (1987) found that there was an emotion congruent effect in human being's behavior. In other words, when somebody feels happy, he/she is more likely to run into positive things, while when he/she feels upset, things around him/her are tend to be negative. Lee et al. (1991) came up with the "investor sentiment theory" which said that the expectations of trader on future earnings were easy to be affected by sentiment volatility. According to some psychological researches, the behavior decision-making and judgment of people can be affected by emotions. Wright and Bower (1992) put forward that people made positive evaluations on many things when they were in good moods, increasing investment and consumption for example. Isen (1993) proposed that people would simplify the cognitive processes to help themselves make decision when they were happy. Liu et al. (2000) and Song et al. (2003) gave objective evidence of the interaction between Chinese stock market and investor sentiment. Wu et al. (2016a,b) found that investor sentiment could not only be used to predict the current stock yield but also the long-term (or intertemporal) stock yield. Other researches on the influences of investor sentiment on stock yield are conducted by Baker and Wurgler (2006), Kaplanski and Levy (2010), Levy and Yagil (2011), Brown and Cliff (2004). Due to space limitations, the details of these researches will not be given.

Air pollution influences stock yield in different ways. Guo and Zhang (2016) proposed that air quality affected the preference and decision-making of such stock market participants as supervision department, listed company, and local and non-local investors through policies (Oberndorfer and Andreas, 2006; Mulatu et al., 2010; Kong et al., 2012), sentiment (Thaler 1993; Daniel et al., 1998; Bullinger 1990; Schottenfeld 1992; Nowakowicz-Debek et al., 2004; Coates and Herbert 2008; Hirshleifer 2001) and market expectations (Banerjee 1992; Yang et al., 2004) respectively. Then the trading behaviors (direction, quantity, and timing) are determined, through which the stock yield is affected eventually. It should be pointed out that policy, sentiment, and market expectation are closely related and influence each other.

This paper conducts an empirical analysis with regression discontinuity model, through which endogency can be avoided effectively. Yu and Wang (2011) believed that regression discontinuity, second to random experiment, was an approach which could analyze the correlations between variables through the effective utilization of realistic constraint conditions. Lee (2008) proposed that regression discontinuity was widely applied as it could avoid the endogency in parameter estimation and faithfully reflect the correlations between variables. This paper attempts to find out whether the stock yield of enterprise will be affected when AQI reaches a certain threshold. Regression discontinuity is quite suitable for the case and thus is used in this paper.

3. Introduction to indices and data

3.1. Air pollution level

Using which kind of index to measure air pollution level is one of the research focuses. Khanna (2000) put forward the air pollution index system by means of comprehensively evaluating multiple pollutants. Kyrkilis et al. (2007) and others proposed aggregate air quality index. It is worth mentioning that Zhou has made in-depth research on this field. Taking the use of the "loss of information" thinking, Zhou et al. (2006) constructed a composite environmental index (CEI) which could objectively measure the environmental pollution level. By means of empirical study, simulation as well as comparative analysis, Zhou and Ang (2009)

Table 1
Air quality index and the corresponding air quality level.

Air Quality Index	Air Quality Level	Air Pollution Level	Interpretation and Suggestion
0–50	I	Excellent	The air is free from pollution and the air quality is satisfactory. Normal activities are suggested for all people.
51–100	II	Good	The air quality is acceptable and only some extremely susceptible people will be slightly influenced by particular pollutants and they should have less outdoor activities.
101–150	III	Lightly Polluted	The symptoms of susceptible people will be slightly aggravated. Irritations occur to health people. Children, elders, and individuals with breathing and heat problems should reduce longtime-intense outdoor exercise.
151–200	IV	Moderately Polluted	The symptoms of susceptible people will be further aggravated. The heart and respiratory system of healthy people may be influenced. Individuals with heart and breathing problems should avoid longtime-intense outdoor exercise. Health people should restrict outdoor exercise.
201–300	V	Heavily Polluted	The symptoms of people who suffer from heart and lung diseases will be significantly aggravated and they will experience reduced endurance in activities. Symptoms occur to healthy people widely. Children, elders, and individuals with heart and lung diseases should stay indoors and stop outdoor exercise. Healthy people should reduce outdoor exercise.
300+	VI	Severely Polluted	Health people will experience reduced endurance in activities. There are strong symptoms which may trigger some illnesses. Children and elders should stay indoors and avoid exercise. Healthy people should avoid outdoor activities.

believed that the Shannon-Spearman measure (SSM) had more advantages in the construction of Composite indicators (CI); Zhou et al. (2017) also formulated meaningful environmental indices by further employing A nonparametric frontier approach. These researches are very profound with high reference value. Currie et al. (2009) and Heutel and Ruhm (2013) took the maximum of environmental pollution to study the influence of pollution on human health and mortality respectively, which provides ideas for this research. Chen et al. (2012) and Xi and Liang (2015) pointed out that the maximum of daily API and annual API from key control cities could not only reflect the pollution level but also easiest to be recognized by the public and finally influenced the investment decision. And therefore, this paper also applied the maximum of environmental pollution measurement index. In 2012, the Chinese government published the AQI index,[2] the most authoritative announced index to evaluate air pollution level at the present, and therefore, this paper employed the maximum of daily AQI as the measurement index of air pollution. The AQI data were collected from the Daily Report of Air Quality in Cities published by Ministry of Environmental Protection of PRC in the December of 2014, 2015 and 2016 with the statistic units being key cities.[3] The maximum and minimum of AQI in December from 2014 to 2016 were 500 and 63 respectively. According to the discontinuity provided by Table 1, the discontinuities in this section included 100, 150, 200 and 300. Referring to the method put forward by Xi and Liang (2015), we made the regression analysis of multiple-cutoffs effect with the maximum of AQI in December.

3.2. Stock yield

This paper has selected the stock yield of heavy pollution listed enterprises in December from 2014 to 2016 as samples based on the studies made by Li (2003) who after examination and empirical analysis of the month effect in China's stock market, found that there exist December Effect in our country's stock market rather than the January effect commonly existing in both mature and newly emerging stock markets. And therefore, we selected the stock yield index in December.

3.3. Control variable

Arnott et al. (1989) proposed that foreign earnings, P/B ratio (price to book ratio), P/E ratio (price to earnings ratio), and enterprise scale were the four main influence factors of stock yield. Liu et al. (2000) conducted an empirical study on the basis of earnings per share. Chen et al. (2001) through cross-section multiple factor analysis, proposed that enterprise scale and P/B ratio had significant explanatory power to the stock yield on Chinese stock market. He (2001) put forward that the reciprocal of price to earnings ratio had a significant impact on stock yield. This paper, based on the above researches, selects the control variables of stock yield. They are enterprise scale, P/B ratio, stock yield, and the reciprocal of P/E ratio. Besides, some unavailable Control Variables of several enterprises are regarded as missing data.

3.4. Heavy pollution enterprise

In 2013, the Ministry of Environmental Protection issued the *Notice on Special Emission Limits on Air Pollutants*[4] which has classified 19 provinces into key control area. For the key control area, special limits for the key air pollutants in thermal power industry, iron and steel industry, petrochemical industry, cement industry, non-ferrous metals industry, and chemical industry as well as coal-fired boiler are applied. Therefore, the enterprises in the six industries in the 19 provinces can be used as the sample source. According to Liu et al. (2000), the six industries can be further divided into 12 heavy pollution industries.[5] We firstly selected heavy pollution A-share listed enterprises of provincial key cities in CSMAR and deleted those with ST, namely, to remain the listed enterprises in normal situation. And then the stock yield of these

[2] API simplifies the concentration of regularly monitored SO_2, nitrogen oxide and total suspended particles as unitary conceptual exponential value and hierarchically manifests the level of air pollution as well as air quality. It is applicable to represent the short-term air quality and tendency of a city. Compared with API, AQI has also been added with pollutants like $PM_{2.5}$, CO and ozone.

[3] The AQI data of some key cities are incomplete or missing on December 2013 and before, and therefore, the sampled time period spanning from 2014 to 2016.

[4] According to the *Notice on Special Emission Limits on Air Pollutants*, the six industries in major monitoring areas include thermal power industry, iron and steel industry, petrochemical industry, cement industry, non-ferrous metals industry, and chemical industry. The key control area contains 19 provinces (autonomous regions/municipalities). They are Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Guangdong, Liaoning, Shandong, Hubei, Hunan, Chongqing, Sichuan Province, Fujian, Shanxi, Shaanxi, Gansu, Ningxia, and Xinjiang.

[5] According to the *Industry Classification Standard for Listed Company* (2012 Edition) issued by China Securities Regulatory Commission, the above six industries are further divided into 12 sub-industries: B07 (petroleum and natural gas extraction), B08 (ferrous metal mining), B09 (nonferrous metal mining), C19 (leather and fur products and shoes), C25 (petroleum processing, coking, and nuclear fuel processing), C26 (manufacture of chemical raw materials and chemicals), C28 (manufacture of chemical fibers), C29 (rubber and plastics products), C30 (manufacture of non-metallic mineral), C31 (ferrous metal smelting and rolling), C32 (Non-ferrous metal smelting and rolling), and D44 (production and supply of electricity and heat).

heavy pollution listed enterprises in December from 2014 to 2016 were chosen from RESSET and meanwhile the stock yield as well as all outliers existing in the control variables were winsorized, finally obtaining 684 observation data.

The point here is that it was not until January 1, 2013 that the Chinese government disclosed the monitoring data of $PM_{2.5}$. This paper has assumed that the variables of air pollution would have gradually exerted significant influence on the stock yield since 2013. In order to compare the influence of air pollution on the stock yield before and after the year 2014 as well as to verify whether 2014 is the "first year" when air pollution began to significantly influence the stock yield, this paper has also collected the data about API from 2009 to 2013[6] as well as data about other indicators (Stock yield, Control Variable, Heavy Pollution Enterprise) during this period to comparatively analyze the influence on the stock yield of API from 2009 to 2013 and AQI from 2014 to 2016. The empirical result is shown in "4.4 Comparative analysis".

4. Empirical model, results and analysis

4.1. Empirical model

Based on the classification standard on AQI in China, a multi-discontinuities regression model is established (see Table 1).

The following study is to find out where there is a jump in the earnings management index of enterprise with AQI being around 100, 150, 200, and 300. The steps are as follows: First, determining the discontinuities (AQI = 100, AQI = 150, AQI = 200 and AQI = 300). Assuming that the samples near the discontinuities are random, these samples are identical in characteristics and have no significant differences. As a result, the omitted variable bias in empirical process is avoided (Hahn et al., 2001). Second, the samples over the discontinuities fall into treatment group and those under the discontinuities fall into control group. In the grouping of samples, the method proposed by Brollo et al. (2013) is used. The samples between different discontinuity intervals are divided into two parts from the middle. Those covered in $\left[\frac{A_{j-1}+A_j}{2}, A_j\right)$ belong to control group while those covered in $\left[A_j, \frac{A_j+A_{j+1}}{2}\right)$ belong to treatment group. Based on the research of Hahn et al. (2001), the regression discontinuity model is established:

$$\gamma_{it} = \alpha^{*}D_{it} + f(a_{it} - A_j) + D_{it}^{*}f(a_{it} - A_j) + X\beta + \delta_t + \eta_i + \xi_z + \mu_{it} \quad (1)$$

where $a_{it} \in \left[\frac{A_{j-1}+A_j}{2}, \frac{A_j+A_{j+1}}{2}\right]$, $D_{it} = 1\{a_{it} - A_j > 0\}$, γ_{it} is the stock yield of Company i, a_{it} is air quality index, A_j is the jth discontinuity, and $a_{it} - A_j$ is the distance between Sample i and Discontinuity j. $D_{it} = 1\{a_{it} - A_j > 0\}$, a treatment variable, is the function of Continuous Function a_{it} and is determined by the difference between a_{it} and discontinuity. When$a_{it} - A_j > 0$, $D_{it} = 1\{a_{it} - A_j > 0\}$ is 1, otherwise it is 0. X refers to control variable, including Size (enterprise scale) and P/B ratio (price to book ratio). δ_t is time fixed effect (a time trend which does not change along with individual). η_i is individual fixed effect (an individual difference which does not change with time). ξ_z is discontinuity fixed effect. Error Term μ_{it} is the cluster of all industries. $f(a_{it} - A_j)$ is the function of Execution Variable $(a_{it} - A_j)$. $D_{it}^{*}f(a_{it} - A_j)$ refers to the function forms that may exist on both sides of control discontinuity. Formula (2) shows the discontinuity effect.

$$\gamma_{it} = \sum_{J=1}^{m} \alpha_J^{*}D_{it}^{*}A_J + (1 + D_{it})f(a_{it} - A_j) + f(a_{it} - A_j)^{*}A_J + X\beta + \delta_t + \eta_i + \mu_{it} \quad (2)$$

where a_J is the influence coefficient of air quality level on stock yield around Discontinuity j.

4.2. Empirical results and analysis

Table 2 shows the comprehensive discontinuity effect as well as the cutoff effect of the influence of air quality level on the stock yield in December from 2014 to 2016. The results are as follows.

Table 2 shows the regression result of the annual maximum of AQI by means of equation (1). In order to make the result more robust, the first order function, the second order function as well as the third order function of AQI are chosen as control variables. It can be seen from the second to the fourth column of Table 2 that from the perspective of the comprehensive discontinuity effect, the stock yield increases with air quality levels, from −0.0015 to −0.0005 with small ascensional range. When the discontinuity is 100 (AQI = 100), the stock yield has distinctively positive effect. When the discontinuity is 150 and 200 (AQI = 150 and AQI = 200), the stock yield is nearly positively relevant. However, when the discontinuity is 300 (AQI = 300), the air quality and stock yield are negatively relevant and statistically significant.

To improve the robustness of results, this paper, conducts regression test under different bandwidths. The omitted variable bias in empirical process is settled by assuming the samples near the discontinuities are randomly distributed. Considering the sample loss may be caused by small bandwidth and the variable omission may be caused by large bandwidth, this paper sets the bandwidth at 25 (half of the distance between two adjacent discontinuities) 25[7]. In empirical analysis, the bandwidths are reduced to 15, 20, and 25 respectively. As is shown in the Columns 5–7 in Table 2, the standard regression results and the local linear regression results of the three bandwidths obtained through linear function are quite close. The above analysis is based on the approach proposed by Xi and Liang (2015).

Based on the above result, when the air quality is better, for example (AQI = 100), the investors may in high spirit and therefore, the stock yield and air quality are positively relevant. When the air pollution is not too severe (for instance, AQI = 150 and AQI = 200), then its influence on stock yield changes from positive to negative, which reflects that the upgrading of air pollution may influence stock yield. While when the discontinuity is 300, namely, the air pollution is severe, the stock yield in all function forms all present negative values, showing that severe air pollution may arouse public attention and the stock yield may decrease since relevant government departments or regulatory organs take corresponding measures to constrain the high-energy emission of heavy pollution enterprises; or the stock yield is influenced by the investors' mood. The above result will further undertake the robustness test in the next step.

[6] As is known that the global financial crisis broke out in 2008. And therefore, the beginning year of API was set as 2009 with the purpose to avoid the shock of the financial crisis on China's stock market. Additionally, since 2014, China's key control cities have begun to comprehensively replace API with AQI and thus the ending year of API was set as 2013.

[7] The bandwidths of the last two Discontinuities 200 and 300 are 50.

Table 2
Discontinuity impact of AQI on stock yield in December from 2014 to 2016 with control variables.

	Standard Regression			Bandwidth = 20	Bandwidth = 15	Bandwidth = 10
	Linear Function	Quadratic Function	Cubic Function			
Overall Discontinuity Effect	−0.0015	−0.0005	−0.0005	0.0017	−0.008	0.003
	(0.005)	(0.007)	(0.008)	(0.009)	(0.012)	(0.014)
AQI = 100	0.028**	0.038**	0.041**	0.029**	0.024	0.052*
	(0.013)	(0.017)	(0.017)	(0.013)	(0.021)	(0.029)
AQI = 150	−0.0005	0.003	0.008	0.0008	0.009	−0.008
	(0.006)	(0.008)	(0.009)	(0.008)	(0.013)	(0.025)
AQI = 200	0.0015	0.003	−0.0008	0.003	−0.053***	−0.055
	(0.007)	(0.008)	(0.011)	(0.011)	(0.019)	(0.046)
AQI = 300	−0.016 (0.013)	−0.020	−0.011	−0.054**	−0.085**	−0.033
		(0.017)	(0.018)	(0.028)	(0.037)	(0.043)
Is control variable included	No	No	No	No	No	No
Sample Size	684	684	684	426	322	232

Notes: (1) *, **, and *** respectively means Statistic t is significant at 10%, 5%, and 1% confidence levels; (2) the values stand for overall discontinuity effect and the regression coefficient of discontinuity. The values within brackets are standard deviations.

4.3. Robustness test

4.3.1. Continuity of execution variable (AQI)

To find out whether the yearly maximum of AQI is controlled by local government, a continuity check on the execution variable $a_{it} - A_j$ (the distance between Sample i and Discontinuity j) is made through the approach proposed by Mehra and Sah (2002) to detect the jumps at different discontinuities. The check results are shown in Fig. 1.

According to the check results of each discontinuity, the confidence intervals of the density function estimate at both sides of the discontinuity are almost overlapped and therefore, the discontinuities are continual and there exist no controlling behavior. It is possible that the government has no necessity or find it difficult to manipulate the daily maximum of AQI since the AQI is reported and real-time updated every day.

4.3.2. Continuity check on control variable

A continuity check is performed on control variables so as to detect the jumps of control variables at different discontinuities, through which the effect of control variable on regression results can be known. The regression results are influenced by control variable if jumps are detected. Based on the model proposed by Xi and Liang (2015), there is:

$$x_{it} = \alpha^* 1\{a_{it} - A_j \rangle 0\} + (1 + D_{it}) f(a_{it} - A_j) + \delta_t + \eta_i + \xi_z + \mu_{it} \quad (3)$$

where x_{it} refers to control variables. There are no jumps at discontinuity if α is small. The results are presented in Table 3.

Based on the check test of each variable at each discontinuity of AQI, it can be seen that the control variable scale, the price book ratio, the 1/price book ratio as well as the earnings per share are all insignificant in the form of the first order function and therefore, they can be all regarded as control variables. However, after adding these four variables, it is found that the price book ratio and 1/price book ratio can to a large degree reduce the significance of the discontinuity regression result and therefore, both of them are eliminated from control variables during the empirical process. At last, only scale and earnings per share are regarded as control variables and the regression results are shown in Table 4. It can be seen that the result of Table 4 is almost consistent with that of Table 2.

4.4. Comparable analysis

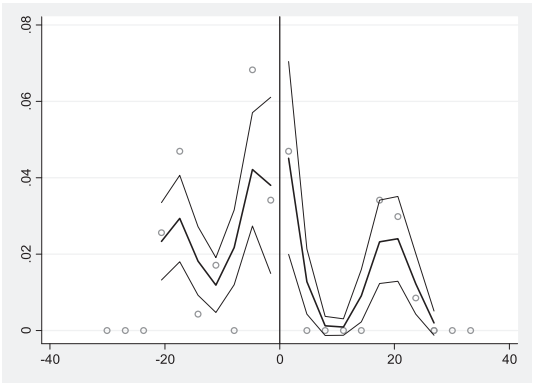
With the purpose to compare the influence of air pollution on the stock yield before and after 2014, this paper has collected data about API from 2009 to 2013 and used equation (1) as well as equation (2) to obtain the regression analysis, finding that the influence of API on the stock yield is not significant. But when the API is 300 (API = 300), the influence coefficient of the stock yield are all negative values. The regression result is shown in Table 5.

Comparing the result in Table 4 (the influence of AQI on the stock yield) with that in Table 5 (the influence of API on the stock yield), we can find that when air pollution becomes increasingly serious, its influence on the stock yield gradually tends to be negative; meanwhile, since 2014, when the AQI is 300 (AQI = 300), the influence of air pollution on the stock yield has been negative and statistically significant.

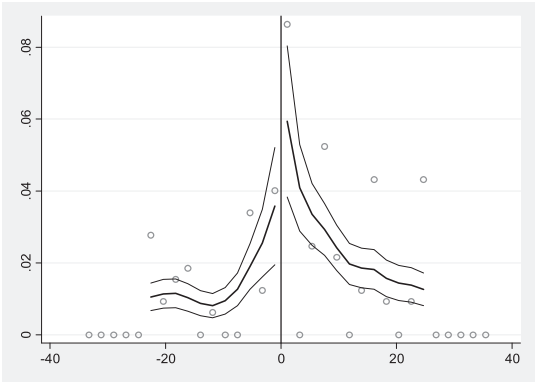
Meanwhile, through the air pollution index test before 2014 in Beijing, Hu et al. (2014) found that there was no remarkable relevance between air pollution and stock yield. And therefore, it can preliminarily conclude that 2013 may be the “first year” when the Chinese society began to take air pollution seriously. In addition, since 2014, heavy air pollution has exerted negative influence on the stock yield because of the lag effect. In fact, Chinese government started to release the air quality data of major cities in 2013. On Jan.1, 2013, China, according to the new air quality standard, officially released the key pollutants and AQI of Beijing-Tianjin-Hebei Region and 74 cities the first time, marking the completion of the first stage of monitoring task under new standard. The information is updated every hour so that the public can know about air quality in time. Haze is regarded as a serious environmental pollution problem for the first time in the report on natural disasters of 2013 released by the Disaster Reduction Center of Ministry of Civil Affairs. Public media started to make considerable reports on haze. In 2013, the News Broadcast, CCTV's national news program, gave an 8-munite report on the haze weather in China for the first time. In People's Daily, the official media of Chinese government, from 2011 to 2016, the pieces of reports on haze weather in 2011, 2012, 2013, and 2014 respectively are 3, 4, 40, and 26. The number increased sharply in 2013 and remained large in 2014. As the Chinese government and the public both pay high attention to haze weather, the air pollution has gradually developed into a social focus from an environmental problem since 2013.

5. Conclusions

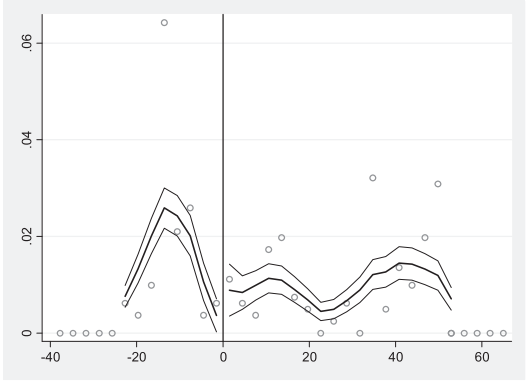
This paper collected the data of listed enterprises in six heavy



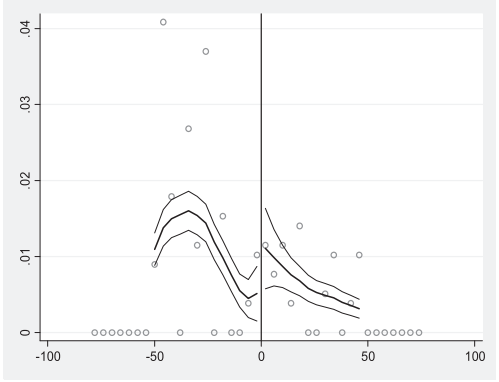
(a)



(b)



(c)



(d)

Table 3
Continuity check on control variable.

	Control Variable (definition)			
	Size: the aggregate value is natural logarithm			
	P/B Ratio (price to book ratio)			
	1/P/E (1/price to earnings ratio)			
	EPS (earnings per share)			
	Linear Function			
	Size	P/B Ratio	1/P/E	EPS
Overall Discontinuity Effect	−0.037	−0.312	0.002	−0.028
	(0.052)	(0.349)	(0.003)	(0.030)
AQI = 100	0.02	−0.477	0.0008	−0.045
	(0.121)	(0.814)	(0.007)	(0.071)
AQI = 150	−0.05	−0.346	−0.002	−0.038
	(0.063)	(0.421)	(0.004)	(0.036)
AQI = 200	−0.078	−0.159	0.004	0.037
	(0.072)	(0.486)	(0.004)	(0.042)
AQI = 300	0.16	−0.574	0.009	0.026
	(0.120)	(0.827)	(0.007)	(0.071)
Observation Value	700	679	646	684

Notes: (1) *, **, and *** respectively means Statistic t is significant at 10%, 5%, and 1% confidence levels; (2) the values stand for overall discontinuity effect and the regression coefficient of discontinuity. The values within brackets are standard deviations.

pollution industries in the key control cities in China from 2014 to 2016 and analyzed the correlation between air quality and stock yield through regression discontinuity model. The empirical results show that, when the discontinuity is 300 (AQI = 300), there shows a significant negative effect on the stock yields of the listed enterprises. The results agree well with the investor sentiment theory which holds that severe air pollution may affect investor sentiment and make investors feel pessimistic about the expectations of stock market earnings, leading to the decline in stock yield. According to Guo and Zhang (2016), another possibility for the stock yield reduction is that supervision department has taken measures to restrict heavy pollution enterprises for the high emissions concerned by the public. No matter what causes the reduction of stock yield, server air pollution, surely has negative influences on the stock yield of listed enterprise according to the empirical results. The results also show that Discontinuity 300 (AQI = 300) can be regarded as a threshold at which air pollution starts to exert a significant negative effect on stock yield. Besides, through comparing the influence of API from 2009 to 2013 on the stock yield as well as combining with researches made by Hu et al. (2014), it can be preliminarily concluded that the year 2014 can be regarded as a watershed after which negative influences become significant gradually.

In view of the abovementioned findings, the following suggestions are made:

First, severe air pollution has a negative influence on economic development. As most of the key control cities in China are in the middle and later periods of industrialization, the emission of polluted air is high and air pollution cannot be eliminated in a short time. Consequently, when the air pollution passes a certain level, the city image, investment attraction, public sentiment, as well as earnings of listed enterprise will be impaired, which will further stunt the economic growth of city. Therefore, air pollution should never be neglected in order to maintain the economic growth of city.

Second, the harmfulness of air pollution should be faced

Fig. 1. Check results of density function at Discontinuities 100(a), 150(b), 200(c) and 300(d).

Table 4
Discontinuity impact of AQI on stock yield in December from 2014 to 2016 without control variables.

	Standard Regression			Bandwidth = 20	Bandwidth = 15	Bandwidth = 10
	Linear Function	Quadratic Function	Cubic Function			
Overall Discontinuity Effect	−0.0006	−0.0005	0.012	0.004	−0.004	0.005
	(0.003)	(0.007)	(0.009)	(0.009)	(0.011)	(0.014)
AQI = 100	0.026**(0.012)	0.032*	0.035**	0.026**	0.016	0.044
		(0.017)	(0.017)	(0.013)	(0.020)	(0.029)
AQI = 150	0.001	0.003	0.009	0.003	0.012	−0.0056
	(0.006)	(0.007)	(0.009)	(0.007)	(0.012)	(0.024)
AQI = 200	0.003	0.006	0.0006	0.003	−0.046**	−0.050
	(0.007)	(0.003)	(0.011)	(0.011)	(0.018)	(0.045)
AQI = 300	−0.020*	−0.021	−0.012	−0.047*	−0.075**	−0.026
	(0.012)	(0.017)	(0.018)	(0.027)	(0.036)	(0.042)
Is control variable included	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	684	684	684	426	322	232

Notes: (1) *, **, and *** respectively means Statistic t is significant at 10%, 5%, and 1% confidence levels; (2) the values stand for overall discontinuity effect and the regression coefficient of discontinuity. The values within brackets are standard deviations.

Table 5
Discontinuity impact of API on stock yield in December from 2009 to 2013 with control variables.

	Standard Regression			Bandwidth = 20	Bandwidth = 15
	Linear Function	Quadratic Function	Cubic Function		
Overall Discontinuity Effect	0.0002	−0.001	0.0002	−0.002*	−0.001(0.001)
	(0.0007)	(0.001)	(0.001)	(0.001)	
API = 100	0.0001	0.0002	0.0006	−0.0001	0.002
	(0.0008)	(0.0009)	(0.001)	(0.001)	(0.002)
API = 150	−0.0005	−0.0002	0.0004	−0.0008	−0.0004
	(0.0006)	(0.0008)	(0.0009)	(0.0008)	(0.001)
API = 200	0.0003	−0.0003	−0.001	−0.002	−0.001
	(0.0009)	(0.001)	(0.002)	(0.001)	(0.002)
API = 300	−0.0008	−0.004	−0.002	0.0001	−0.002
	(0.002)	(0.004)	(0.005)	(0.003)	(0.005)
Is control variable included	Yes	Yes	Yes	Yes	Yes
Sample Size	720	720	720	541	434

Notes: (1) *, **, and *** respectively means Statistic t is significant at 10%, 5%, and 1% confidence levels; (2) the values stand for overall discontinuity effect and the regression coefficient of discontinuity. The values within brackets are standard deviations. (3) The sample is too scarce to report the regression result when API = 300 in December from 2009 to 2013.

seriously. There have been many research findings showed that air pollution had serious negative influences on people's health both physically and psychologically. This paper found that the real impact of air pollution on the society started to show in the year of 2013 when Chinese government faced the harm of air pollution. Due to the high attention the public paid on air pollution, haze, an environmental problem, has gradually developed into a political one which evaluates the governing capacity of Chinese government since 2016 (Wu et al., 2016a, b). The government, intentionally or unintentionally, starts to restrict the forecast and new report on haze weather. As a result, air pollution problem fades from the public view. It does not help to bury one's head in the sand while tackling the air pollution of city. Only by facing air pollution seriously, can the whole society eliminate air pollution with collective wisdom and concerted efforts.

At last, other less developed Chinese cities and foreign cities should learn a lesson from the key control cities in China during development. In fact, when the public realize the seriousness of air pollution, the society will try to exert pressure on government in different ways, resulting in the negative growth of economy. For example, in 2013, the Chinese government started the official monitoring on air quality and released the data of AQI, after which the stock yields of the heavy enterprises in key control cities decline. Therefore, the government should try to maintain equilibrium in economic development, public will, city image, and environmental protection, only by which can the city alleviate the negative effect produced by climate change and air pollution and achieve the sustainable development.

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